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AN ECOLOGICAL STUDY OF IPS CONFUSUS IN NORTHERN CALIFORNIA

Progress Report - Seasons of 1947 and 1948

By

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CONTENTS

		Page
I.	INTRODUCTION	1
II.	PROGRAM FOR THE 1947 AND 1948 SEASONS.	1
III.	GENERAL IPS SITUATION FOR THE 1947 AND 1948 SEASONS.	2
IV.	TREE PHYSIOLOGICAL FACTORS ASSOCIATED WITH IPS BEHAVIOR. . . .	3
	A. Effect of Age of Tree on Brood Production in Slash.	3
	B. Tree Growth in the Burney Area.	3
	C. Phloem Moisture in Slash.	3
	D. Phloem Moisture in Living Trees	4
	1. Phloem Moisture Seasonal Trend	4
	2. Phloem Moisture Gradient in Living Trees	5
	3. Phloem Moisture and Insect Hazard.	5
	4. Phloem Moisture and Phloem Thickness Associated with Tree Class and Risk. . . .	6
V.	CLIMATIC AND EDAPHIC FACTORS ASSOCIATED WITH IPS BEHAVIOR. . .	7
	A. Soil Moisture.	7
	B. Air Temperature.	7
	C. Precipitation	8
VI.	DISCUSSION	8
VII.	SUMMARY.	9

TABLES

		Page
Table 1.	EFFECT OF AGE OF TREE ON BROOD PRODUCTION IN SLASH.	11
Table 2.	PRODUCTION OF IPS CONFUSUS PROGENY IN PONDEROSA PINE SLASH VARYING IN PHLOEM MOISTURE CONTENT	12
Table 3.	PHLOEM MOISTURE SEASONAL TREND.	13
Table 4.	SAMPLING STUDY OF PHLOEM.	14
Table 5.	HOURLY FLUCTUATION IN PHLOEM MOISTURE--HAT CREEK. . . .	15
Table 6.	PHLOEM MOISTURE GRADIENT IN LIVING TREES.	16-17
Table 7.	ASSOCIATION BETWEEN PHLOEM MOISTURE IN THE BASE OF LIVING TREES, AVAILABLE SOIL MOISTURE, AND HAZARD ZONES.	18
Table 8.	PHLOEM MOISTURE BY KEEN'S TREE CLASS, BLACKS MOUNTAIN--PLOT 47-2.	19
Table 9.	PHLOEM MOISTURE BY RISK, BLACKS MOUNTAIN--PLOT 47-2.	20
Table 10.	HOUR-DEGREE AIR TEMPERATURE AT HAT CREEK.	21
Table 11.	DIFFERENCES IN ECOLOGICAL FACTORS ASSOCIATED WITH IPS DEVELOPMENT.	22

FIGURES

		Page
Figure 1.	RELATIONSHIP BETWEEN PHLOEM MOISTURE OF A LARGE SAMPLE WITH THAT OF A SMALL PLUG.	23
Figure 2.	Photograph: RESIDUAL LOSS FROM IPS ALONG A POWER-LINE CLEARING ON THE STARTT RANCH.	24
Figure 3.	Photograph: LARGE GROUP KILL BY IPS IN RESIDUAL TIMBER ADJACENT TO A POWER-LINE CLEARING NEAR FOUR CORNERS IN THE BURNEY AREA	25
Figure 4.	Photograph: HEAVY RESIDUAL KILL BY IPS IN SECOND-GROWTH PINE NEAR MCARTHUR.	26
Figure 5.	TREE GROWTH AT HAT CREEK	27
Figure 6.	ASSOCIATION BETWEEN PHLOEM MOISTURE IN SLASH MATERIAL AND IPS SUCCESS	28
Figure 7.	SEASONAL PHLOEM MOISTURE TREND IN LIVING TREES	29
Figure 8.	PHLOEM MOISTURE IN LIVING TREES.	30
Figure 9.	PHLOEM MOISTURE GRADIENT IN LIVING TREES	31
Figure 10.	PHLOEM MOISTURE AND HAZARD ZONE.	32
Figure 11.	SOIL MOISTURE, WARNERS BRIDGE, AT 9 INCHES.	33
Figure 12.	AIR TEMPERATURES AT HAT CREEK.	34
Figure 13.	HOUR-DEGREE SEASONAL TEMPERATURE..	35
Figure 14.	ACCUMULATED VARIATION FROM MONTHLY MEAN PRECIPITATION, HAT CREEK	36
Figure 15.	ACCUMULATED VARIATION FROM MONTHLY MEAN PRECIPITATION, HAT CREEK (February through July). . .	37

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I. INTRODUCTION

The seasons of 1947 and 1948 mark the third and fourth years, respectively, of intensive ecological studies of Ips in Northern California. The previous two years were spent largely in exploring promising leads for future development. These preliminary studies showed that certain ecological factors appeared to play a dominant role in the behavior of Ips outbreaks. Among some of the more important were: the physical factors of light, temperature, and moisture; nutritional factors of quality and quantity of food; and climatic factors affecting site conditions.

It was observed that the timing of cutting and the subsequent treatment of slash were of great importance in Ips outbreaks in the Burney Area. Cuttings made from April through early July appeared to furnish ideal host material for population build-up. Cuttings made earlier or later usually created no serious problems. Cuttings where the slash was treated by lopping usually gave less trouble than those where the limbs were left attached. It was also observed that attack in living trees was restricted to several months in late summer and early fall and did not occur at other times of the year. The timing of these attacks in living trees coincided with certain physiological and environmental factors. Such attacks occurred after tree growth had ceased and when the tree was in a dormant condition. It also coincided with the period when the soil moisture was at its seasonal minimum. It was also observed that attack occurred in the top portion of the tree and never in the base unless the trees were very small. This combination of circumstances suggested that there might be a moisture deficiency in living trees during the period of successful attack, and that this deficiency might be greater in the top portion than in the base. For these reasons, particular attention was given to the problem of possible moisture deficiencies in the phloem of living trees during the study of 1947 and 1948.

II. PROGRAM FOR THE 1947 AND 1948 SEASONS

The field program for the 1947 and 1948 seasons was designed to attempt to check these hunches on moisture deficiencies, with an intensive study of the phloem moisture in living trees at different times of the year and in different parts of the tree. Studies were also conducted on phloem moisture content of slash to determine if this factor had any bearing on the success of Ips broods. Other physiological factors investigated included tree growth

and age. Climatic and edaphic factors investigated included those of air temperature, soil moisture, and precipitation.

The method of collecting samples for phloem moisture varied from 1947 to 1948. In 1947 an area of about ten square inches was used as the sample size. The point where the sample was to be taken was selected at random and an area of about 4x4 inches square was marked off on the bark around the point selected. The outer bark was carefully removed with as little injury to the phloem as possible. The ten-square-inch sample was then taken from this area and immediately placed in an air-tight container. The samples were then taken to the laboratory, weighed, oven dried to a constant weight at 100° C., then reweighed, the can weight deducted and the moisture content computed on a percentage basis of the oven-dried weight. In 1948 the same general procedure was followed except that an arch punch was used for cutting out the phloem sample. This permitted the cutting out of a uniform disc 1¼ inches in diameter at the point of the sample; these were taken in duplicate for each sample. The samples were wrapped in light aluminum foil to prevent their drying out. The same general procedure of drying was followed as in the previous year. This method was checked very carefully before it was adopted, and it was found to yield the same precision as the larger sample. It was found that this gave a slightly higher value than the larger sample, apparently due to the compression of moisture around the edges when the punch was forced into the phloem. This was a constant factor amounting to about five percent, and the arch punch samples were adjusted by that amount. (Figure 1.) The chief advantage in the sampling with the arch punch was that a living tree could be repeatedly sampled with very little injury. It was also a much more rapid method of sampling.

III. GENERAL IPS SITUATION FOR THE 1947 AND 1948 SEASONS

During the 1947 season Ips damage was quite heavy and widespread throughout Northern California. The California State Division of Forestry carried on a number of control jobs in Lassen, Butte, Shasta, Siskiyou, and Trinity Counties. A total of about 8,000 infested trees and poles were treated in this district. Heavy damage occurred in practically all areas where shotgun cuttings were made in the spring. The total number of trees killed in the Burney area was comparatively low, but the reason for this is believed to be the lack of critical slash areas. The whole character of logging has changed in the Burney Flat Area within recent years. From 1944 to 1946, spring logging on the Burney Flat unit was very common and widespread. In 1947 there were only two small logging operations during the spring of the year. In addition to this, there were three pole line cuttings made in the spring of the year in this general area. It is significant that every one of these spring cuttings created conditions leading to killing in the reserve stands. (See Figures 2, 3, and 4.) It is believed, therefore, that the 1947 season was potentially very favorable for Ips damage in reserve stands.

The 1948 season was radically different as far as Ips killing in reserve stands was concerned. Practically no killing occurred in the whole Burney Area during the 1948 season. However, there were only three small spring cuttings made in this area in 1948. None of these developed killing in the reserve. A survey of all of the areas where control had been carried out by the State the previous season showed practically no Ips killing late in

October 1948, except around Greenville in Plumas County and near Weaverville and Hayfork in Trinity County. Control action probably had some influence on this decline, but it is suspected that climatic factors played a very important part in this sudden decline in damage. In addition to the great difference in Ips damage between the 1947 and 1948 seasons, there was also a significant difference in practically all the ecological factors associated with Ips behavior. A comparison of some of these differences in ecological factors between the two years is presented below.

IV. TREE PHYSIOLOGICAL FACTORS ASSOCIATED WITH IPS BEHAVIOR

A. Effect of Age of Tree on Brood Production in Slash.

Data collected on Ips during the 1945 and 1946 seasons in the Burney Area appeared to show that slash from young trees produced better broods than did slash from overmature trees. Another example of this apparent effect was found in two cuttings made in the Burney Area in January 1948. One area was the Forest Service sanitation-salvage cutting on the Burney Flat near the Black Ranch where practically all of the trees cut were in the overmature class. The other cutting was just north of Old Four Corners, on the west side of Burney Creek, where a cutting was made in a second-growth pole stand. The first cutting was made on January 26, 1948 and the second on January 28. Population samples from these cuttings showed about four times as many progeny produced in the younger age slash. The average progeny per square foot of bark surface was 27.8 in the older cutting and 111 in the younger cutting. (Table 1.) This matter of the effect of quality of slash material on Ips production is a point which has not been conclusively demonstrated, and further data should be collected on this phase of the problem in the near future.

B. Tree Growth in the Burney Area.

To date, there has been very little association shown between tree growth and susceptibility to Ips attack. Growth measurements have been maintained for the Burney Area for the past ten years. These measurements have been obtained from aluminum growth bands, on five sample pole-size trees adjacent to each weather station; the bands furnish information on the start of growth, the periodic increment by weekly intervals throughout the season, and information on the date of cessation of growth. Figure 5 furnishes a graphic comparison between the 1947 and 1948 seasons. The start of the 1948 growth was about one month behind the 1947 season, and growth ceased about two weeks earlier than for 1947. It may be noted that the total growth for the 1948 season was significantly below that for the 1947 season. This means that for these two seasons, at least, the heavy Ips damage coincided with the year of 1947 when the growth was more than it was in 1948 when no damage occurred.

C. Phloem Moisture in Slash.

It has long been suspected that the phloem moisture content of slash has an important bearing on the success of Ips broods produced therein. General observations indicated that if the phloem moisture of slash was very

low, the corresponding production of Ips broods would be low. It was also observed that if phloem moisture was extremely high, the brood production was low. An experiment was undertaken in 1948, under laboratory conditions, to test the success of Ips broods in slash with varying moisture contents. Three broad levels of phloem moisture were used: Low level, averaging about 50% moisture; medium level, averaging about 125% moisture; and high level, averaging about 190% moisture. The material used in the low level tests was dried down to the required level in a specially constructed oven at about 170°F. The material used in the other levels was selected from field material having the required moisture content. This slash material was cut into approximately two-foot sections and placed in individual cages; then a uniform number of beetles were introduced to force attack. When the brood had developed to the callow adult stage, a progeny count was made for each level.

The results of this preliminary test are presented in Table 2 and Figure 6. From this it would appear that low and high moisture levels both produce very poor broods, with optimum brood development at the 125% to 150% level. These data are not in any sense conclusive, and this experiment should be replicated at least one more season in order to check on these results.

D. Phloem Moisture in Living Trees.

The investigation of phloem moisture in living trees was conducted in four different phases: (1) A study of the phloem moisture seasonal trend; (2) a study of the phloem moisture gradient in living trees; (3) a study of the association of phloem moisture in living trees and hazard zones; and (4) a study of the association of phloem moisture and phloem thickness with tree class and risk.

1. Phloem Moisture Seasonal Trend.

As has been pointed out previously, Ips attack of living trees does not occur until late in the summer in the Burney Area. It was speculated that there might be a lowering in the phloem moisture which would coincide with the time of Ips attack. Studies were undertaken in 1947, and continued in 1948, to study this possibility. The work for the 1947 season did not start until July 10, when two trees were sampled at Hat Creek. This continued at approximately weekly intervals until mid-September with four periods of sampling through the winter months. Sampling started at Warner's Bridge and Cornaz on August 8 with five trees sampled at each of these locations. In 1948, five trees each were sampled at all three locations at approximately bi-weekly intervals from April through September.

The 1947 data appear to show that there was a definite decline in phloem moisture in the base of living trees from early July to mid-September, when a considerable increase in phloem moisture took place. This increase coincided with the first fall rains. (Table 3). The 1948 data were extremely variable and failed to confirm the tendency observed in 1947. There was some indication of a decline in phloem moisture from early April until about mid-May, when an apparent increase occurred; this continued upward until mid-June, when there was another downward tendency until late July when a very sudden increase in phloem moisture apparently took place. This was the maximum for the season.

There appeared to be another drop in mid-August followed again by another increase in mid-September. (Figure 7.)

As the 1948 season progressed, it was apparent that the trend was not following that of 1947, and an attempt was made to determine what was causing the apparent wide variation in phloem moisture. A sampling study was undertaken to determine the amount of variation which could be expected due to sampling, and it was found that this was not expected to exceed 5% for any group of five trees at each period of sampling. (Table 4.) Studies were also conducted to see if the time of day at which the sample was collected had any effect on phloem moisture. It was found that there was an apparent hourly fluctuation during the day, but this was not of sufficient magnitude to greatly influence the results. (Table 5.) There seems to be no satisfactory explanation for the behavior of phloem moisture in the base of living trees during the 1948 season. It is quite obvious that the problem of the association of phloem moisture with other ecological factors is not as simple as was at first thought. It will be necessary to carry out further studies on this problem before we can make any prediction as to its possible association with Ips behavior.

2. Phloem Moisture Gradient in Living Trees.

It is a well established fact that Ips attack in living trees, unless they are very young, is restricted to the top portion. So far, no one has advanced a plausible theory as to why attack should be restricted to the top portions of trees. It was speculated that the phloem moisture in the top portion might be lower than in the basal portion, and it was decided to explore this possibility. Studies of this phase of the problem were conducted in both 1947 and 1948 during late August and early September. This study was conducted by collecting phloem moisture samples from the base, mid-top, and tip of trees within a few minutes after they had been cut in logging. Fourteen trees were sampled in this manner on two different sites in 1947, and eighteen additional trees on three areas in 1948.

These data show a very definite lowering of the moisture gradient in living trees, from the base to the top. Of 32 trees studied, the average for all basal samples was 213% phloem moisture, compared to 163% for the mid-top and 128% for the tip. (Table 6, Figures 8 and 9.) These results appear to show that a definite association exists between attack habits of Ips and lower phloem moisture in the top of trees.

3. Phloem Moisture and Insect Hazard.

During the 1944 Ips epidemic in the Burney Area, practically all of the critical slash areas produced heavy killing of reserve timber on these logging areas. In addition, there were other areas of serious Ips damage which apparently were not directly associated with logging slash. In the first example cited above, there did not appear to be any particular association between hazard and Ips damage except in a very broad sense. There were no known infestations in Hazard Zone II, although Hazard Zone III had several areas where damage was severe. In the second example, however, where damage occurred away from logging areas, there appeared to be a definite tendency for such groups to occur in areas of local high hazard. Such groups were commonly

confined to very dry exposed slopes or ridge tops. This suggested a preference for attack in areas of high hazard. Studies were started in 1947 and continued in 1948 on this phase of the problem, to determine if there was any association between hazard zone and phloem moisture in the base of living trees. This phase of the study included a sampling of phloem moisture in the base of four living trees on each of 22 twenty-acre permanent sample plots, representing four degrees of insect hazard. These samples were collected about September 1, when the seasonal soil moisture was at its minimum. Soil samples were also collected on each plot at the time of sampling phloem moisture.

The 1947 study showed that there appeared to be a definite association between hazard zone and phloem moisture in the base of living trees, as may be noted from Table 7 and Figure 10. This appears to show that the higher the hazard zone, the lower the phloem moisture. There also appears to be a broad association between phloem moisture and available soil moisture. It may be noted that the average phloem moisture in the base of living trees in Hazard Zone V was 134%, in Hazard Zone IV, 166%, in Hazard Zone III, 203%, and in Hazard Zone II, 236%. All these differences between zones are highly significant.

The 1948 study confirmed the work done in 1947 as far as general trends are concerned, as may be noted in Table 7 and Figure 10. Again, all differences between hazard zones were highly significant. There was a very marked difference in the phloem moisture level between years for Hazard Zones V and IV. In 1947 the average phloem moisture in Hazard Zone V was 137%; this had increased to 178% in 1948, or an increase of about 30% over that for 1947. In Hazard Zone IV the average phloem moisture was 166% in 1947, and had increased to 193% in 1948, or an increase of about 16%. Both of these differences between years are highly significant. Hazard Zones II and III showed no significant differences between years.

These data furnish evidence leading to the following conclusion: The higher the insect hazard, the lower the phloem moisture. During a year of deficient precipitation and low soil moisture level, phloem moisture appears to be much lower than when precipitation levels are above normal in the higher hazard zones. This may have the effect of lowering the resistance of a tree to Ips attack. This may help explain the preference of Ips in initiating attack in the higher hazard zones when moisture deficiencies are particularly critical at the time of attack.

4. Phloem Moisture and Phloem Thickness Associated with Tree Class and Risk.

It was suspected that phloem moisture might show a definite association with risk, age and crown class based on Keen's Tree Classes. A sample of four trees from each of Keen's 16 tree classes was sampled for phloem moisture on August 30 and 31, 1948, at Blacks Mountain on plot 47-2. This study failed to show any consistent association between phloem moisture and tree class (Table 8) or between phloem moisture and risk (Table 9). Records were also kept on phloem thickness for these samples. This factor of phloem thickness showed a broad association with both crown class and risk. The average phloem thickness for Class A trees was .30 inches; Class B was .24 inches; Class C was .16 inches; and Class D was .13 inches. The average phloem thickness by risk was as follows: Risk 1, .27 inches; Risk II, .20 inches; Risk III, .16 inches; and Risk IV, .13 inches. There did not appear to be any association

between age groups and phloem thickness.

V. CLIMATIC AND EDAPHIC FACTORS ASSOCIATED WITH IPS BEHAVIOR

It has long been suspected that climatic factors have an important effect on Ips behavior. As early as 1924, Person theorized that drought was the primary cause of Ips top-killing in the Cascadel Area on the Sierra National Forest. The 1944 Ips epidemic in the Burney Area coincided with a season very deficient in precipitation and soil moisture. Intensive studies of climatic and edaphic factors have been conducted in the Burney Area for a period of about ten years. During that period we have experienced some years when Ips damage has been severe and others in which it has been very light. As has been pointed out in a previous section of this report, the 1947 and 1948 seasons were markedly different in most respects. In 1947 Ips damage was potentially very serious, and in 1948 it was potentially very light. An attempt has been made to analyze those factors of climate and soil which have shown maximum variation associated with the change in Ips behavior. Three factors which showed maximum differences between years were: Seasonal precipitation, soil moisture, and air temperature. A number of different methods of comparing these data have been tried, and apparently the most significant method of presenting them is through an arithmetical accumulation of the variations from the monthly means. This furnishes what might be called a precipitation or soil moisture pattern which gives a picture of the accumulated effect at any particular month. These factors will be taken up in the following order: A. Soil Moisture; B. Air Temperature; and C. Precipitation.

A. Soil Moisture.

This factor varied markedly between 1947 and 1948. In 1947 the average soil moisture for April was slightly above average, but in each succeeding month there was an accumulated deficit, until by September the accumulated deficiency had amounted to about 10.5%. This was a year of potentially heavy Ips damage. In 1948, when Ips damage was very light, soil moisture started off in April with an excess and kept accumulating each month until by September the excess was 22%. (Figure 11.) Two other years have been compared on this same basis. Note from Figure 11 that the 1944 season had much the same pattern for soil moisture as did 1947; 1944 was the year of the heaviest Ips damage in the Burney Area. 1942 was a year in which losses were very light; note that this has much the same pattern as for 1948, although the magnitude is not the same.

B. Air Temperature.

Air temperature is another factor which varied greatly between 1947 and 1948. In 1947, temperatures were above normal from February until July, when the average for the season reached normal. For the balance of the season, temperatures were below normal, ending the season with an accumulated deficit of about ten degrees. In 1948, temperatures were slightly above normal for January and February, but from that month on until December, temperatures were below normal for every month with an accumulated deficit of about 33 degrees for the season. Note from Figure 12 that the 1944 pattern shows some

resemblance to the 1947 pattern, and the 1942 pattern is somewhat similar to the one for 1948. The above discussion is based on the accumulated variation from the monthly mean. Another way of expressing temperature is on an hour-degree basis. This is based upon the number of hours during which the temperature was above a certain base. Figure 13 shows a comparison of the two years of 1947 and 1948 based on 50 and 70 degrees. The period from February to October has been selected for this comparison because there is little Ips activity before February or after October in the Burney Area. It may be noted from Table 10 and Figure 13 that there was considerable difference in the curves for the period from February to June but little difference for the balance of the season.

The effect of temperature on Ips development is probably two-fold. Low temperatures have a direct effect in slowing down insect development, and in reducing evaporation which tends to conserve soil moisture. High temperatures have the reverse effect. The average low temperature for 1948 slowed down development to the point where one less generation was produced.

C. Precipitation.

Seasonal precipitation is another factor which showed considerable difference between the years of 1947 and 1948. This difference is much more pronounced from February to July than it is from August to January. The 1947 pattern was a gradual declining curve in the accumulated variation from the monthly mean. The 1948 pattern showed a seasonal excess in precipitation from August to about December 1, when it fell below normal and dropped to an accumulated deficit of 4.5 inches in February. From February to July there was above-normal precipitation every month; this brought the seasonal total to slightly above four inches. (Figure 14.) The patterns for three other years have been plotted for the Burney Area. Note from Figure 14 that the 1941-42 pattern bears some similarity to the 1947-48, and that the 1943-44 pattern is almost identical with the one for 1946-47. These were both years of heavy potential Ips damage. The 1945-46 pattern is somewhat erratic but shows a definite trend toward a deficit from December to June. Comparisons have also been made on a shorter term basis, from February to July. (Figure 15.) This shows essentially the same general trend as the longer period comparison, but the latter appears to be slightly superior in its association with the degree of Ips damage.

VI. DISCUSSION

The 1947 season was one characterized by low seasonal precipitation, low soil moisture, and air temperatures slightly above normal. These factors coincided with the heaviest Ips damage in northern California since the 1944 season. The 1948 season was radically different in that seasonal precipitation was well above normal, soil moisture was well above normal from April to September, and air temperatures were well below normal. During this year, Ips damage was the lightest since 1941 in the Burney Area.

It appears that the unfavorable climatic factors operating in 1947 created conditions leading to a serious outbreak of Ips during that season. In 1948 favorable climatic factors apparently prevented any Ips damage in the reserve

stands in the Burney Area. Just how these factors operated to encourage Ips attacks one year and discourage them the other is not clear. It appears that abundant moisture, or the lack of it, had a direct effect on the trees and apparently determines whether Ips attacks are to be successful. A partial explanation may lie in the association of phloem moisture and hazard and in the difference in the phloem moisture gradient from the base to the top of living trees at the time of attack. However, this point has not been conclusively demonstrated, and it will be necessary to know more about the factors which directly influence phloem moisture before it will be possible to evaluate its effect on Ips behavior.

It appears at the present time that seasonal precipitation is the most important single factor in determining the success or failure of Ips attacks in living trees. Indications are that it may be possible to use the seasonal precipitation pattern as a guide in forecasting Ips damage in reserve stands. This phase of the study will be covered in a more detailed report which is now being prepared.

VII. SUMMARY

The 1947 and 1948 seasons have shown a marked difference in most ecological and biological respects. The 1947 season was one of heavy Ips damage throughout most of California. The following season of 1948 was one characterized by very light losses throughout Northern California except for a few local areas. (Table 11.)

Studies of phloem moisture during these two years have shown certain significant trends. It was determined that there is a lowering of the phloem moisture from the base to the top of living trees in late summer. A sample of 32 trees, on different sites and in different years, has shown average phloem moisture at the base to be 213%, at mid-top, 163%, and at the extreme top, 128%. Phloem moisture was found to be closely associated with hazard zone and available soil moisture. No consistent association was found between phloem moisture and tree class or risk. Studies on the seasonal trend of phloem moisture in living trees have shown conflicting tendencies for the two seasons, and no conclusions are possible on this phase of the work at the present time. Preliminary studies under laboratory conditions in 1948 have shown that the phloem moisture content of slash may have an important bearing on Ips development. These data appear to show that the optimum initial moisture content for maximum Ips development is between 125% and 150%, and that phloem moisture above or below this level has a tendency to produce poorer broods.

Studies of climatic and edaphic factors have shown the following significant facts: The 1947 season was very dry with soil moisture below normal during most of the growing season, seasonal precipitation was well below normal, and air temperature was above normal early in the season. The 1948 season was characterized by: Soil moisture well above normal for the whole growing season, seasonal precipitation above normal, and air temperature well below normal for nearly the whole season. This low air temperature appears to have slowed Ips development to the extent that only $2\frac{1}{2}$ broods of Ips were produced in 1948 compared to $3\frac{1}{2}$ in 1947.

It was found that by plotting the accumulated arithmetical variation from the average monthly precipitation, distinctly different precipitation patterns for the two years of 1947 and 1948 were obtained. There appears to be some chance that the precipitation pattern can be used as early as May as a basis of predicting Ips damage the following fall.

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TABLE 1

EFFECT OF AGE OF TREE ON BROOD PRODUCTION IN SLASH

(Basis of Sample: 2 Sq. Ft. of Bark Area Per Tree)

Date Cut	Age of Tree Cut	No. of Tree	No. Progeny Per Sq. Ft.	Progeny per Inch of Egg Gallery
Sanitation-salvage cutting by Forest Service, Burney Flat (Average tree diameter--38")				
Jan. 26, 1948	Overmature	1	23	1.13
		2	40	0.41
		3	35	1.65
		4	16	1.17
		5	25	1.53
TOTAL (Average)			27.8	1.18
Cutting by Schofield, Old Four Corners (Average tree diameter--20")				
Jan. 28, 1948	Immature	11	150	2.12
		12	120	1.50
		13	164	2.38
		14	57	1.32
		15	66	1.86
TOTAL (Average)			111	1.83

TABLE 2

PRODUCTION OF IPS CONFUSUS PROGENY
IN PONDEROSA PINE SLASH, VARYING IN PHLOEM MOISTURE CONTENT

(Under Laboratory Conditions)

Section No.	Moisture Content of Phloem at Time of Attack-- % Dry Weight	Number of Adult Beetles Introduced	Number of Progeny Produced	Progeny Production Ratio
S-1-A	100	72	560	7.8
S-1-B	53	50	150	3.0
S-2-A	57	50	127	2.5
S-2-B	96	72	436	6.1
H-1-A	60	50	151	3.0
H-1-C	190	50	129	2.6
O-1-A	200	80	138	1.7
O-1-B	62)	80	125)	2.1
O-1-C	65)		40)	
O-1-D	125)	80	586)	11.1
O-1-E	132)		303)	
O-2-A	186	50	117	2.3
O-2-B)	132)	50	381)	12.6
O-2-C)	120)		251)	
O-2-D	55)	50	41)	1.3
O-2-E	60)		22)	

561

4·9

TABLE 3

PHLOEM MOISTURE SEASONAL TREND

Seasons of 1947 and 1948

Month	Warner's		Hat Creek		Cornaz		All	
	1947	1948	1947	1948	1947	1948	1947	1948
April		180		206		212		199
May		182		182		190		185
June		192		202		208		201
July		190	210	200		201	210	197
August	150	215	180	236	200	240	177	230
September	138	209	168	230	190	260	165	233

TABLE 4

SAMPLING STUDY OF PHLOEM

36 Duplicate Arch Punch Samples

(First Sample Collected Designated as "X", Second as "Z")

Sample No.	Sample X	Sample Z	Difference
7-A	192	205	13
7-B	231	255	24
7-C	239	224	15
8-A	196	201	5
8-B	218	255	37
8-C	223	203	20
9-A	224	224	0
9-B	178	179	1
9-C	212	238	26
10-A	217	208	9
10-B	165	196	31
10-C	218	231	13
11-A	222	216	6
11-B	214	218	4
11-C	202	184	18
12-A	206	214	8
12-B	207	222	15
12-C	214	210	4
13-A	191	194	3
13-B	243	257	14
13-C	232	230	2
14-A	192	203	11
14-B	226	228	2
14-C	226	222	4
15-A	211	219	8
15-B	240	220	20
15-C	274	247	27
16-A	208	221	13
16-B	208	195	13
16-C	228	211	17
17-A	205	210	5
17-B	235	238	3
17-C	244	249	5
18-A	217	221	4
18-B	231	236	5
18-C	228	202	26
MEAN	217.1	219.1	2.0

Average for 36 samples: 218.1

Sampling error for 36 samples: ± 1.27

Sampling error for 4 samples: ± 5.37

TABLE 5

HOURLY FLUCTUATION IN PHLOEM MOISTURE--HAT CREEK

Three Trees Sampled at Base by Arch Punch--(Duplicate Samples)

Date	Hour	No. Samples	Average Phloem Moisture
8/5/48	7 A.M.	6	225
	8 A.M.	6	216
	9 A.M.	6	209
	10 A.M.	6	206
	11 A.M.	6	209
	12 Noon	6	214
	1 P.M.	6	225
	2 P.M.	6	216
	4 P.M.	6	233
	6 P.M.	6	212
	8 P.M.	6	222
Average			217
8/6/48	7 A.M.	6	230

TABLE 6

PHLOEM MOISTURE GRADIENT IN LIVING TREES

Tree No.	D.B.H.	Ht.	Phloem Moisture--% Base	Mid-top	Tip
		DEER FLAT CUTTING			
		August 5, 1947			
1	44	170	208	192	111
2	32	165	212	183	126
3	54	145	239	205	157
4	44	190	229	174	153
5	34	140	200	169	134
6	24	95	250	159	125
7	52	200	230	154	117
8	36	165	228	161	155
9	46	170	254	167	115
10	38	180	246	164	114
11	36	160	314	227	138
12	50	200	243	243	105
Average		165	237	183	129
		BLACKS MOUNTAIN CUTTING			
		August 11, 1947			
1	44	120	169	154	115
2	42	118	184	182	138
3	36	125	144	143	114
4	38	110	213	162	109
Average		118	178	160	119

TABLE 6--(Continued)

PHLOEM MOISTURE GRADIENT IN LIVING TREES

Tree No.	Risk	Tree Class: Keen	Tree Class: Dunning	D.B.H.	Ht.	Phloem Moisture--% Base	Phloem Moisture--% Mid-Top	Phloem Moisture--% Tip
CORNAZ LAKE CUTTING								
September 10, 1948								
1	2	4C	5	64	155	220	160	156
2	3	4C	5	36	125	178	137	123
3	2	4C	5	50	134	223	153	131
4*	4	4C	5	40	130	207	121	Dead
5	2	4B	5	50	135	159	154	137
6	2	4B	5	60	145	224	156	122
7	3	4C	5	40	120	211	163	137
8*	2	4C	5	42	115	210	140	Dead
9*	3	4C	5	34	125	196	142	Dead
10	3	4C	5	34	125	235	164	154
11*	4	4C	5	26	120	196	Dead	Dead
12	3	3C	3	28	110	190	146	110
13*	4	3C	3	34	132	261	136	Dead
14	3	3C	3	30	132	228	148	129
Average					131	208	153	133
*Trees not included in average								
OLD STATION CUTTING								
August 27, 1948								
1	1	1A	1	12	75	200	138	131
2	1	1B	1	12	70	180	142	139
Average					73	190	140	135
BURT'S CUTTING								
August 24, 1948								
1	2	2A	1	26	130	201	138	120
2	1	3A	1	32	136	221	148	128
3	1	2B	1	24	126	198	139	108
4	2	3C	3	28	128	195	145	128
5	1	3A	3	34	132	207	153	121
Average					130	204	145	121
Average Based on 32 Trees:						213	163	128

TABLE 7

ASSOCIATION BETWEEN PHLOEM MOISTURE IN THE BASE OF LIVING TREES, AVAILABLE SOIL MOISTURE, AND HAZARD ZONES ON 22 TWENTY-ACRE PERMANENT SAMPLE PLOTS IN THE BURNEY AREA

(Samples Collected About September 1 Both Years)

Hazard Zone	No. Trees Sampled		% Available Soil Moisture		Phloem Moisture--%	
	1947	1948	1947	1948	1947	1948
V	4	4	1.0+	-0.5	134	178
IV	28	24	0.6+	1.8+	166	193
III	28	28	3.3+	6.9+	203	215
II	28	28	4.5+	6.5+	236	231

TABLE 8

PHLOEM MOISTURE BY KEEN'S TREE CLASS
BLACKS MOUNTAIN--PLOT 47-2

Collected August 30-31, 1948

	Phloem Moisture--% of Dry Weight				
	A	B	C	D	ABCD
1	170	199	194		
	224	179			
	179	189			
	178				
Average	188	189	194		189
2	185	184	189	196	
	236	197	187	172	
	192	201	197	187	
	204	198	192	168	
Average	204	195	191	181	192
3	165	173	162	224	
	175	145	168	196	
	203	189	174	193	
	195	233	211	182	
Average	185	185	179	199	187
4	167	158	166	150	
	168	165	181	171	
	195	177	181	166	
	182	176	213	181	
Average	178	169	185	167	174
		Averages			
1	188	189	194		189
2	204	195	191	181	192
3	185	185	179	199	187
4	178	169	185	167	174
	189	185	187	182	186

TABLE 9

PHLOEM MOISTURE BY RISK
BLACKS MOUNTAIN--PLOT 47-2

Collected August 30-31, 1948

(These Are the Trees Sampled in Keen's Tree Class)

	Risk I	Risk II	Risk III	Risk IV
	162	158	165	166
	173	185	176	175
	177	150	147	194
	170	167	181	196
	224	165	171	166
	179	168	182	192
	185	190	183	
	175	188	196	
	197	181	212	
	168	195		
	178	224		
	237	233		
	192	172		
	204	198		
	203	187		
	195	187		
	202			
	190			
	189			
	179			
	213			
	168			
	194			
	189			
	195			
Averages:	189	184	179	182

TABLE 10

HOUR-DEGREE AIR TEMPERATURE AT HAT CREEK

Seasons of 1947 and 1948

Month	50°		70°	
	1947	1948	1947	1948
February	35	25	0	0
March	138	42	2	0
April	263	106	42	1
May	488	317	166	57
Total February to May	924	490	210	58
June	483	562	146	187
July	624	684	310	317
August	610	609	268	279
September	484	449	201	145
Total June to September	2,201	2,304	925	928
Total February to September	3,125	2,794	1,135	986

TABLE 11

DIFFERENCES IN ECOLOGICAL FACTORS ASSOCIATED WITH IPS DEVELOPMENT

Seasons of 1947 and 1948

Factor	Total or Average		Departure from Normal			
			Total		%	
	1947	1948	1947	1948	1947	1948
Precipitation:						
Seasonal--						
Aug. to July	17.4 in.	28.6 in.	-7.1 in.	+4.0 in.	-29.0%	+16.0%
Feb. to July	9.8 in.	17.8 in.	-2.3 in.	+5.7 in.	-19.0%	+47.0%
Temperature:						
Feb. to Oct.	56.7°	51.4°	+1.4°	-3.9°	+ 2.7%	- 7.7%
Soil Moisture:						
Average seasonal, W. B.	14.8	20.0	-1.7	+3.5	-10.3%	+21.2%
Phloem Moisture:						
Hazard V	134.0%	178.0%				
Hazard IV	166.0%	193.0%				
No. Generations of Ips	3½	2½				
Tree Growth-- Inches	.111	.089				
Ips Killing in Reserve	Heavy	Light				

FIG. 1

RELATIONSHIP BETWEEN PHLOEM MOISTURE OF A LARGE SAMPLE WITH THAT OF A SMALL PLUG

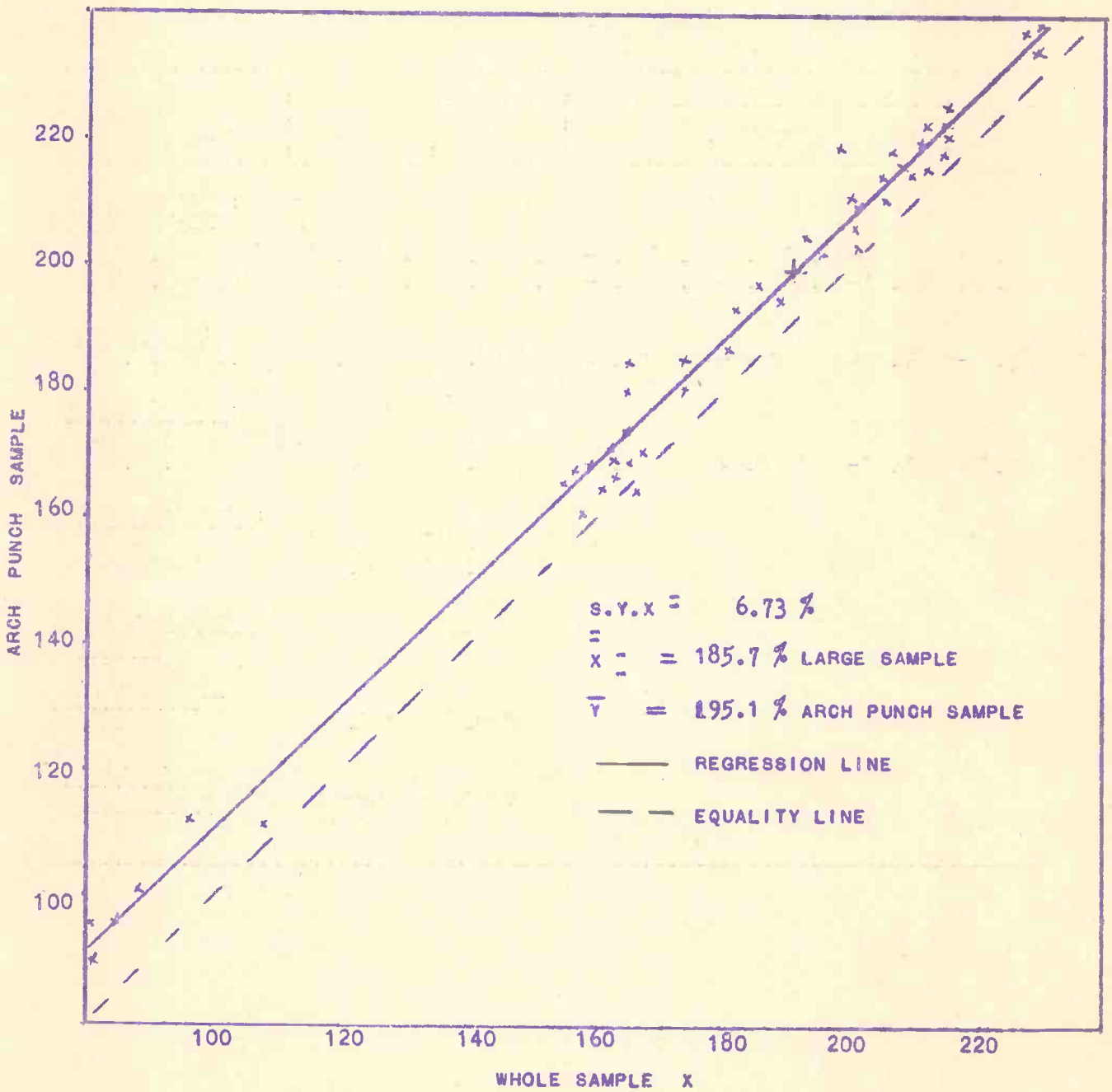


FIG. 2

Residual loss from Ips along a power-line clearing on the Startt Ranch, Hat Creek. Trees were cut in this clearing late in June, 1947. This cutting resulted in Ips' killing 96 trees adjacent to the cutting. (Photo. #13367).

FIG. 3

Large group kill by Ips in residual timber adjacent to a power-line clearing near Four Corners in the Burney Area. There are 27 merchantable trees included in this group. Groups of this character were common along this clearing which was made in late June, 1947. (Photo. #13366).

FIG. 4

Heavy residual kill by Ips in second-growth pine near McArthur. This kill extended along a pole-line clearing made in mid-June, 1947. The trees which were cut in this clearing were not limbed, such as the one in the foreground. Practically all of the trees in the middle of the picture have been killed. The men in the right background are members of the California State Division of Forestry Control Crew working on February 19, 1948. (Photo. #13368).

FIG. 5

TREE GROWTH AT HAT CREEK

COMPILED FROM GROWTH BANDS ON FIVE POLE SIZED TREES

SEASON OF 1947 & 1948

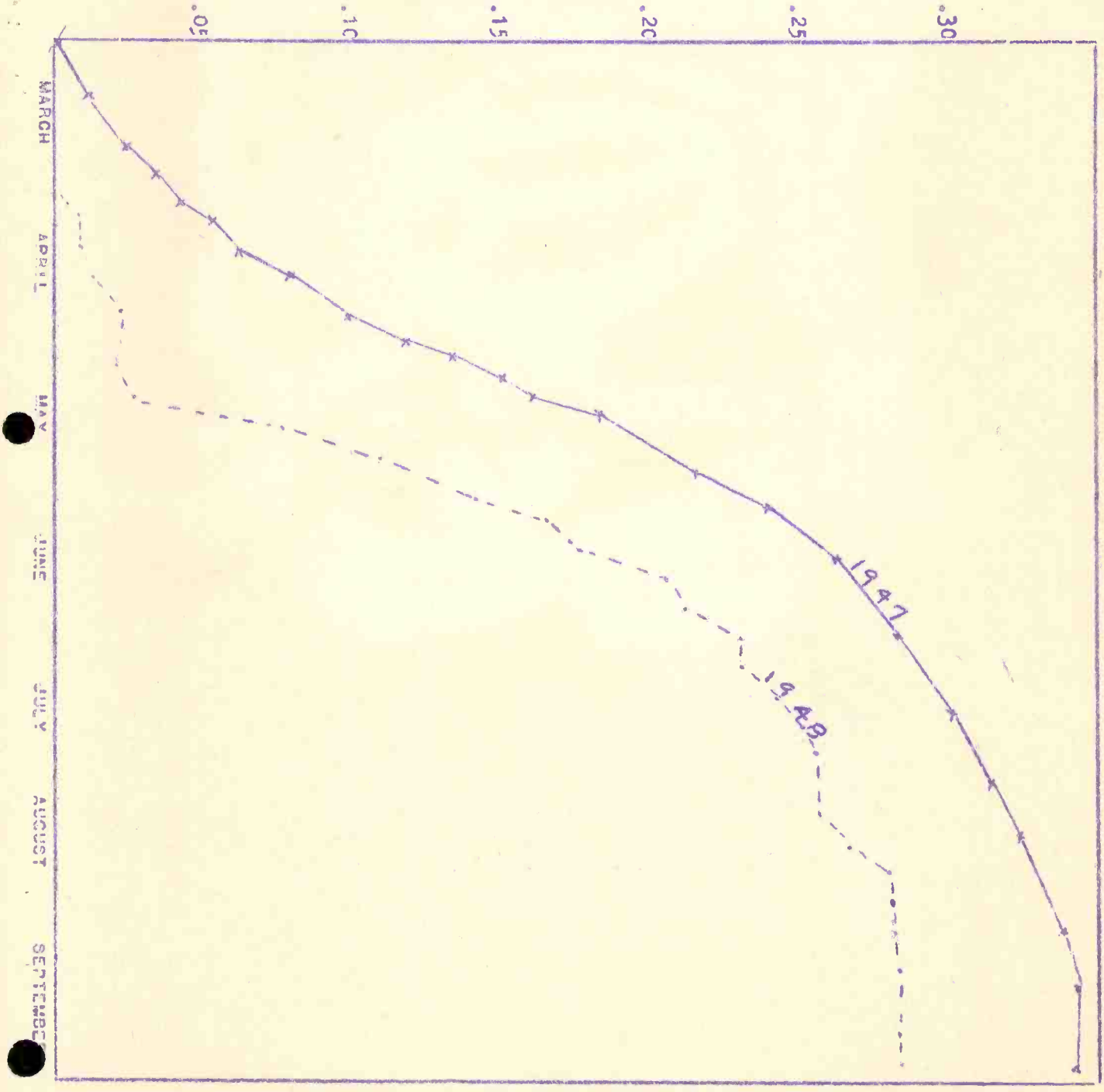


FIG. 6

ASSOCIATION BETWEEN PHLOEM MOISTURE IN SLASH MATERIAL AND IPS SUCCESS
UNDER LABORATORY CONDITIONS

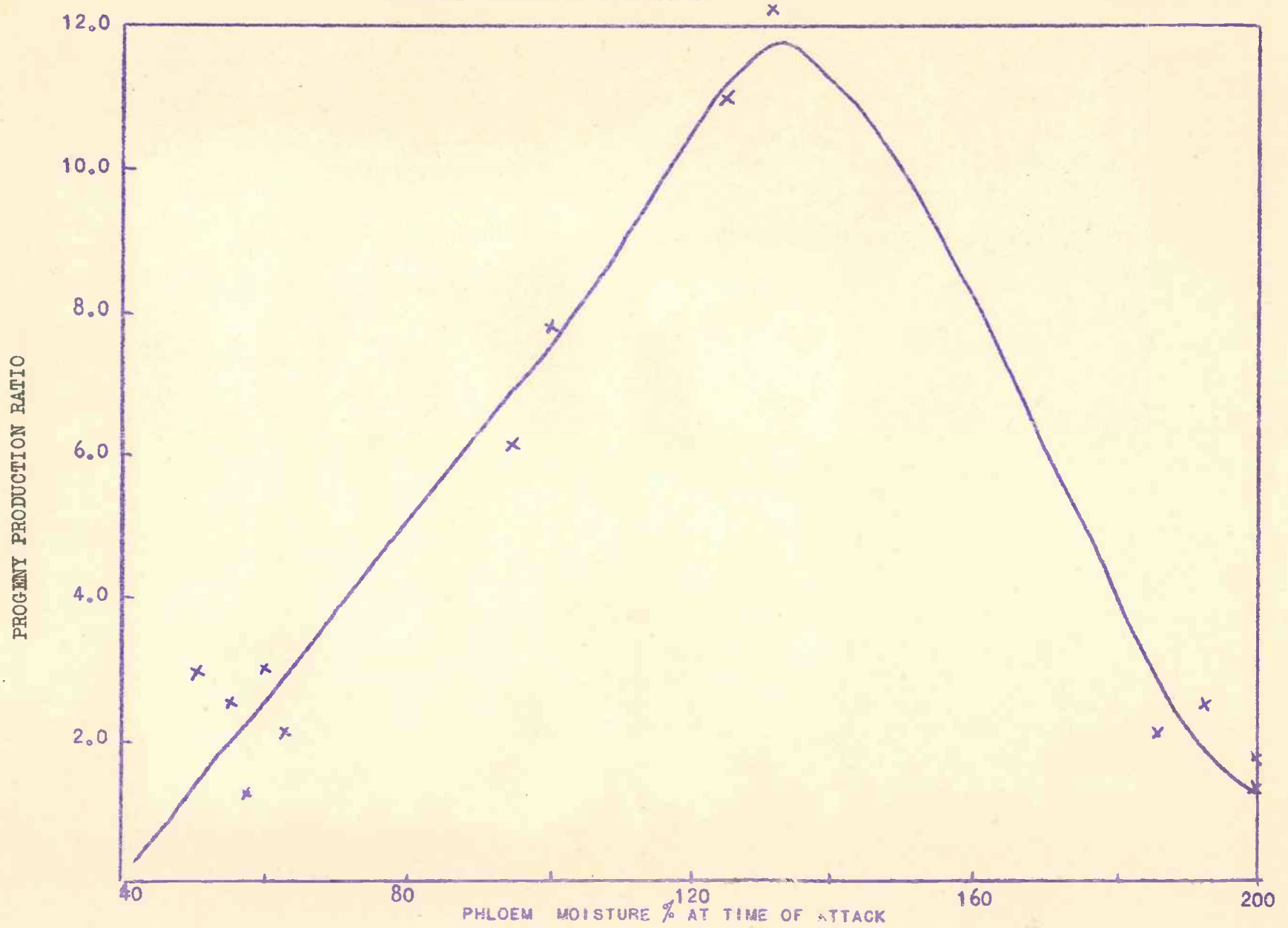


FIG. 7

SEASONAL PHLOEM MOISTURE TREND IN LIVING TREES

SEASON OF 1948

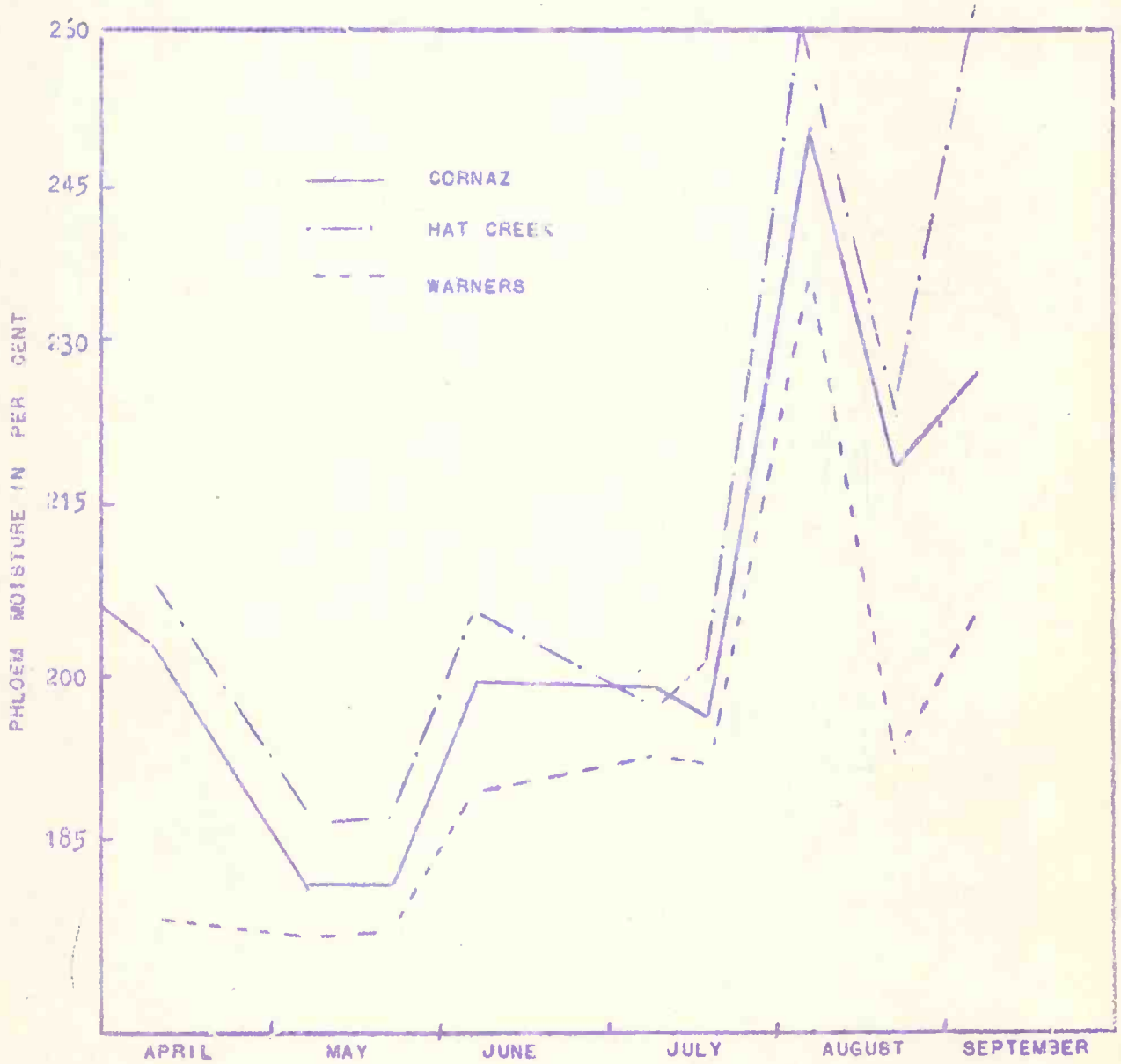


FIG. 8

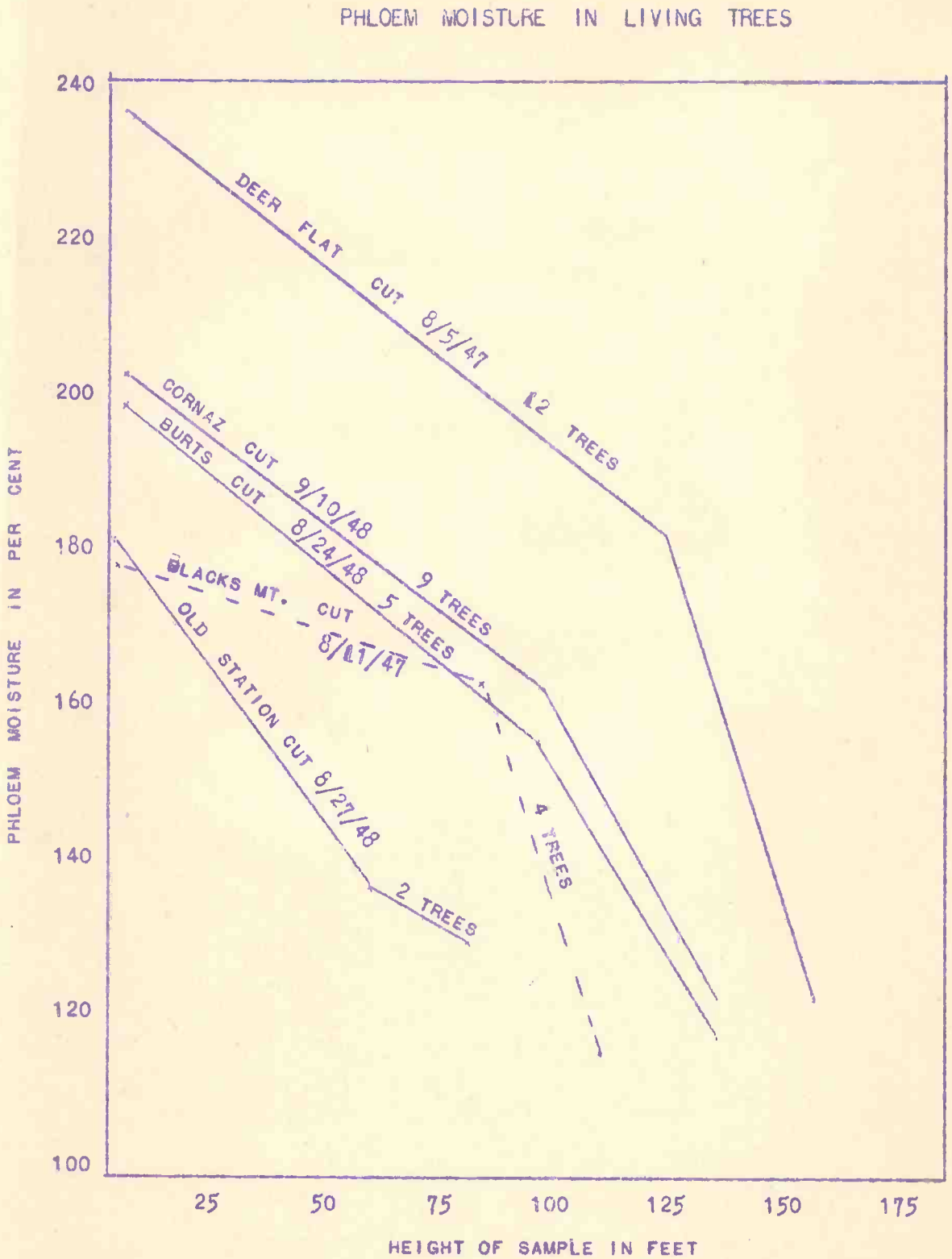

PHLOEM MOISTURE IN LIVING TREES
240
220
200
180
160
140
120
100
PHLOEM MOISTURE IN PER CENT
DEER FLAT CUT 8/5/47 12 TREES
CORNAZ CUT 9/10/48 9 TREES
BURTS CUT 8/24/48 5 TREES
BLACKS MT. CUT 8/11/47 4 TREES
OLD STATION CUT 8/27/48 2 TREES
25
50
75
100
125
150
175
HEIGHT OF SAMPLE IN FEET

FIG. 9

PHLOEM MOISTURE GRADIENT IN LIVING TREES

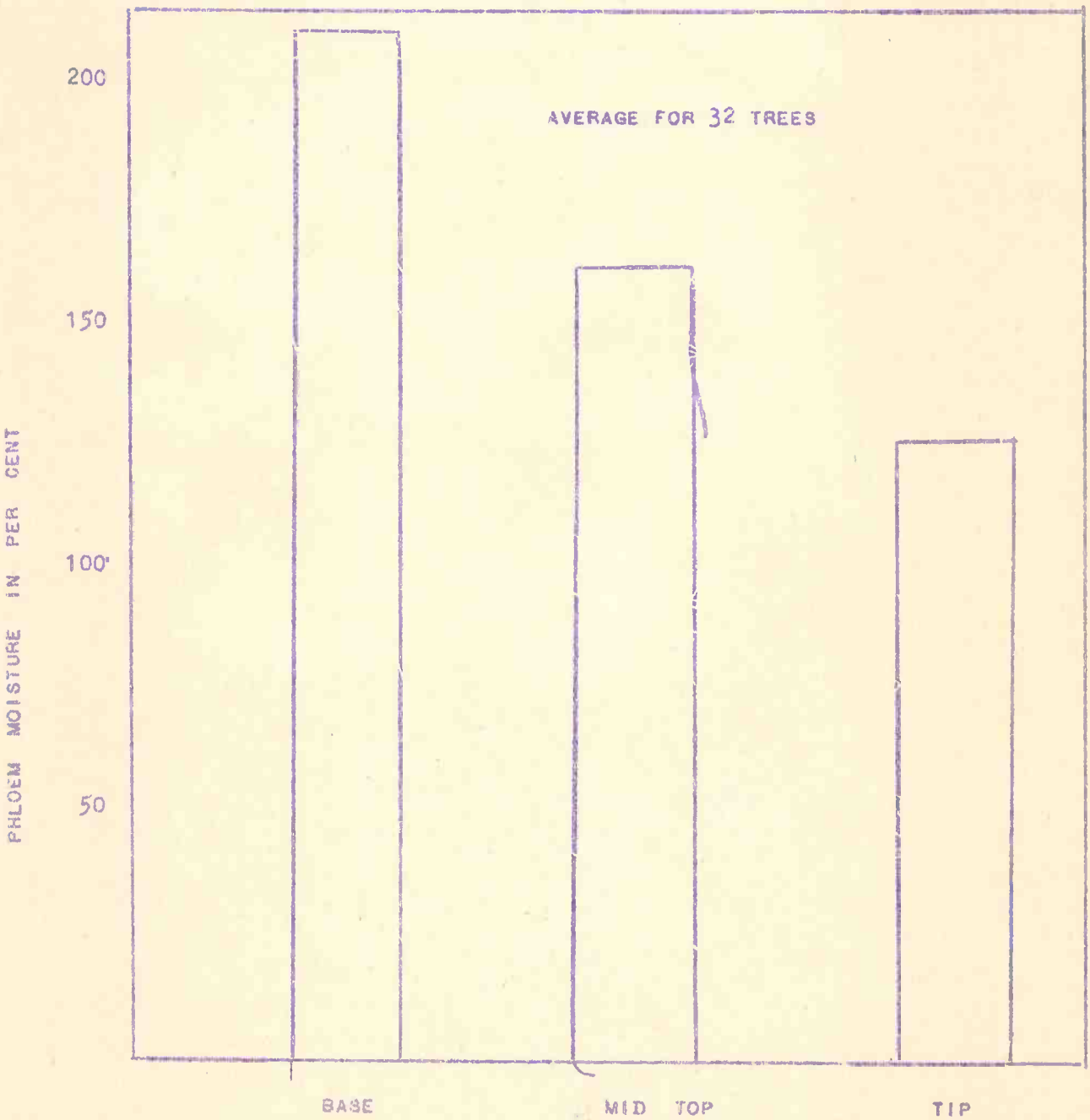


FIG. 10

PHLOEM MOISTURE AND HAZARD ZONE

BASED ON 88 LIVING TREES

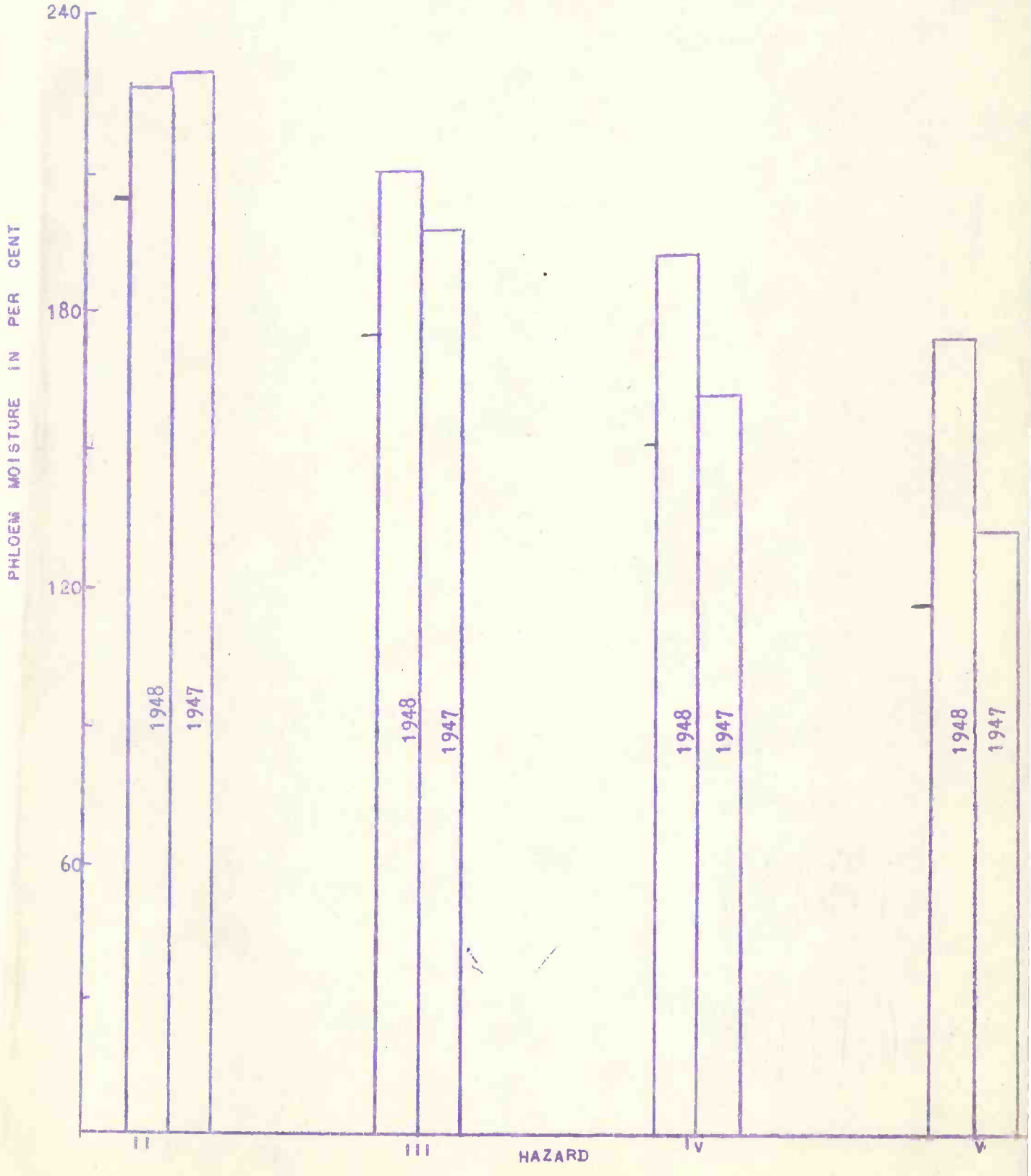


FIG. 11

SOIL MOISTURE WARNERS BRIDGE AT 9 INCHES

ACCUMULATED VARIATION FROM MONTHLY MEAN

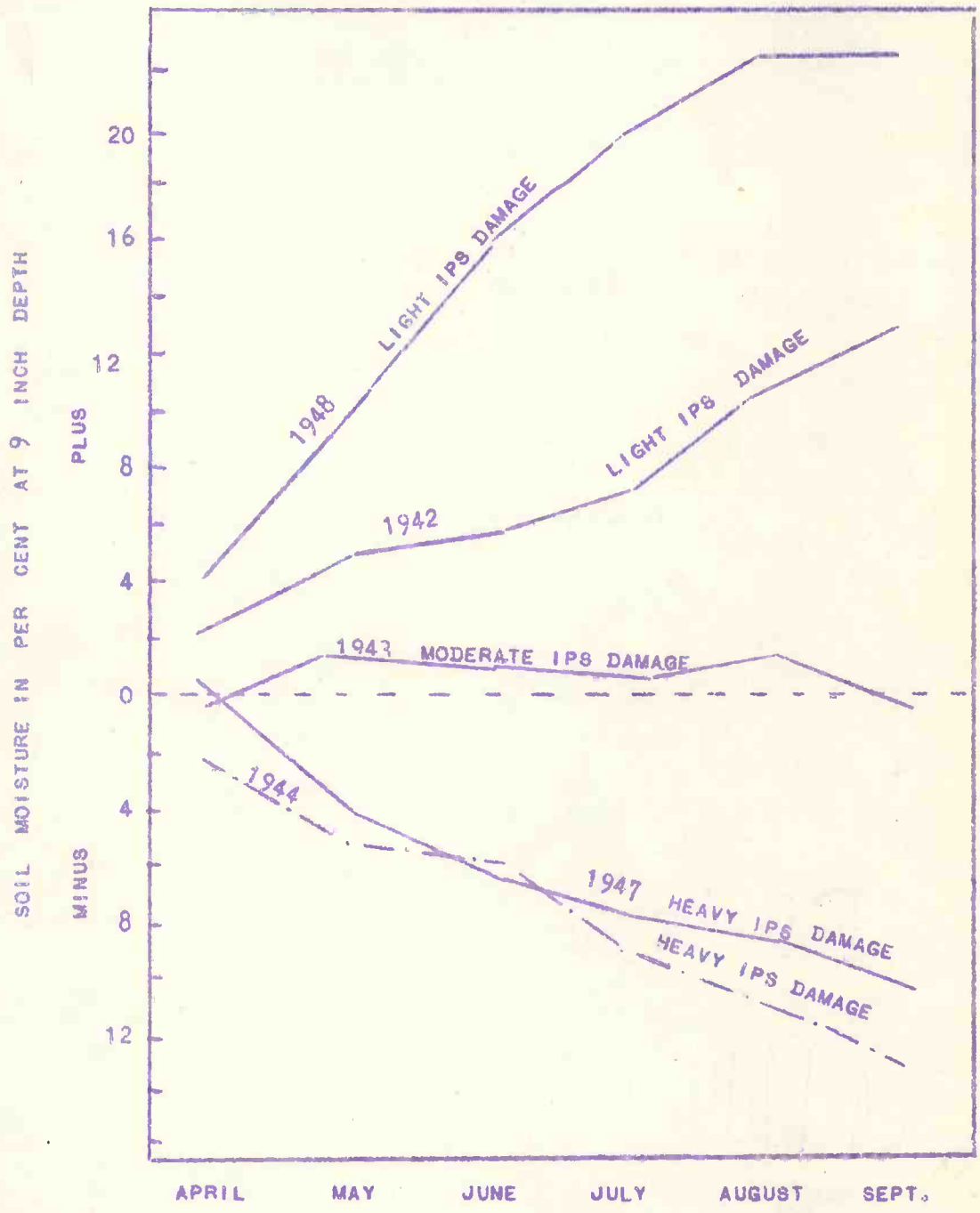


FIG. 12

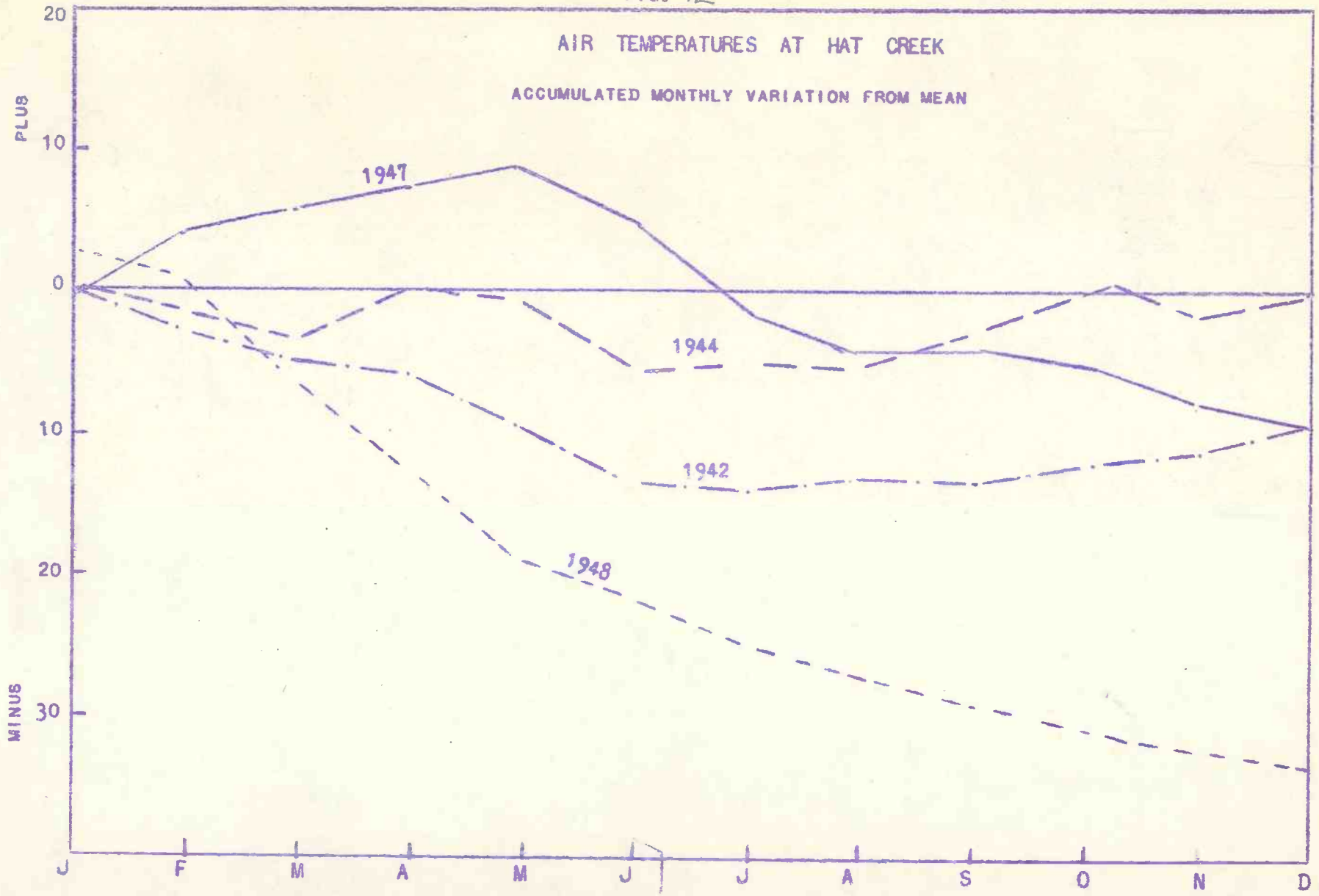

AIR TEMPERATURES AT HAT CREEK
ACCUMULATED MONTHLY VARIATION FROM MEAN
PLUS
MINUS
DEGREES F
20
10
0
10
20
30
1947
1944
1942
1948
J
F
M
A
M
J
J
A
S
O
N
D

FIG. 13

HOUR DEGREE SEASONAL TEMPERATURE

HAT CREEK

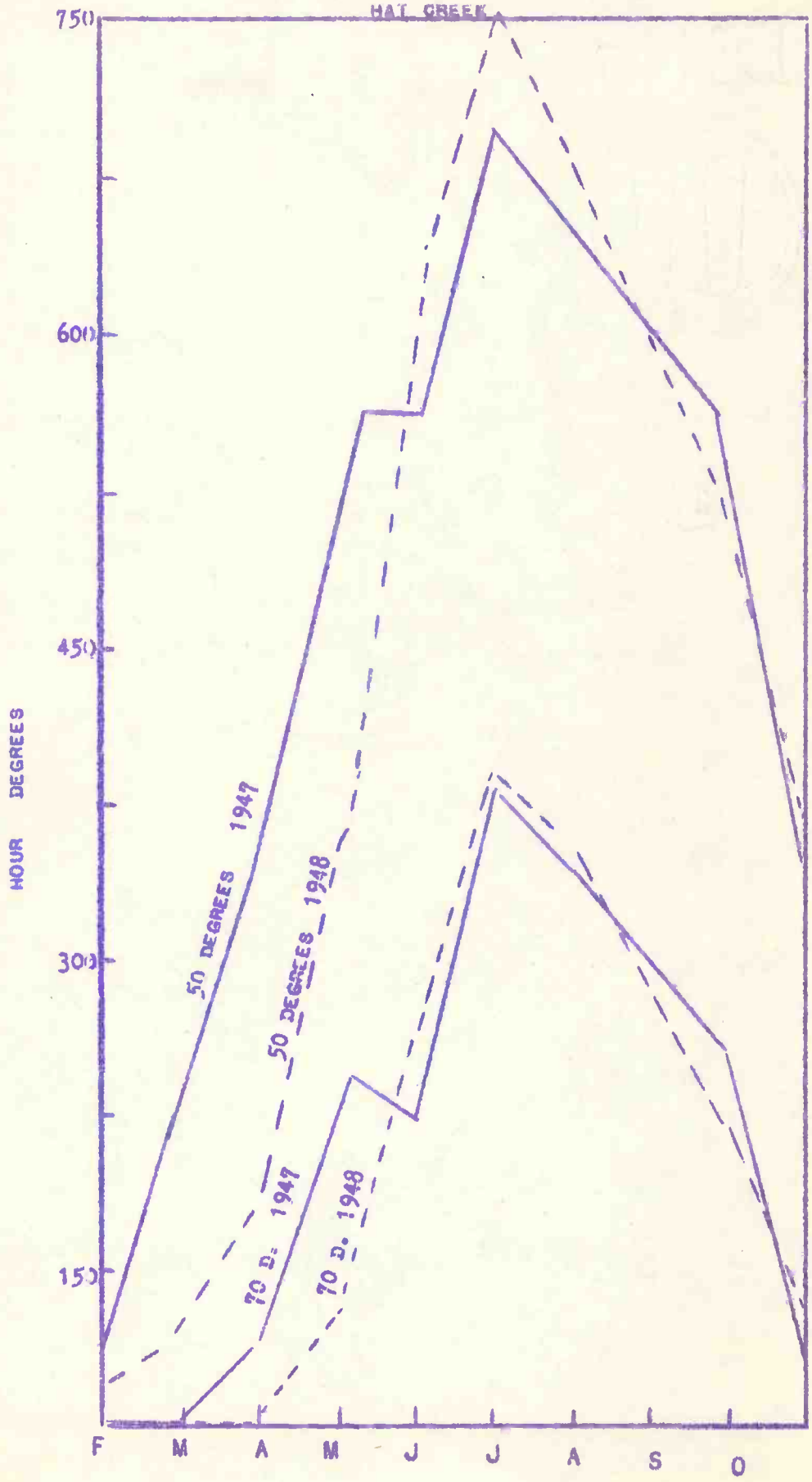


FIG. 14

ACCUMULATED VARIATION FROM MONTHLY MEAN PRECIPITATION
HAT CREEK

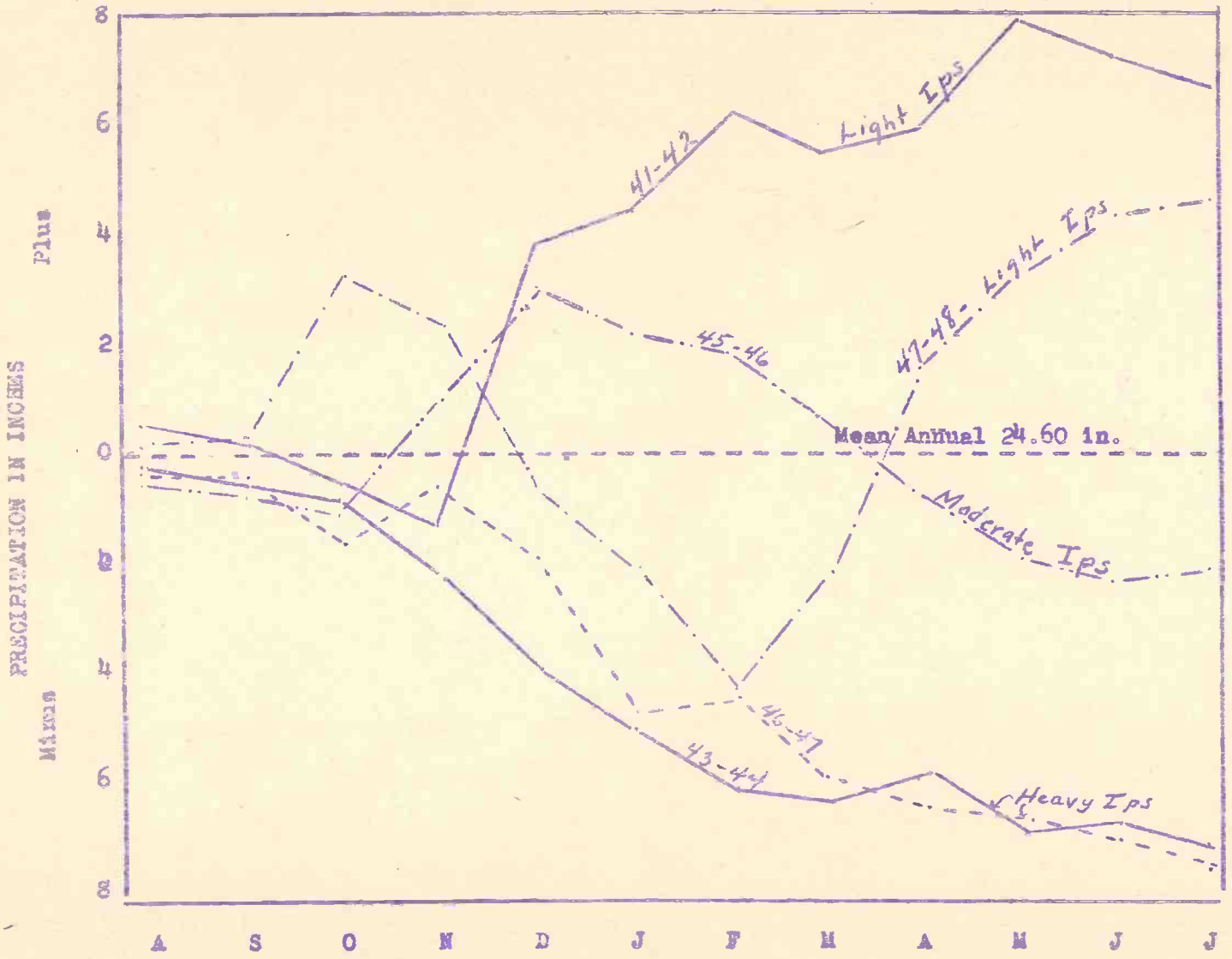
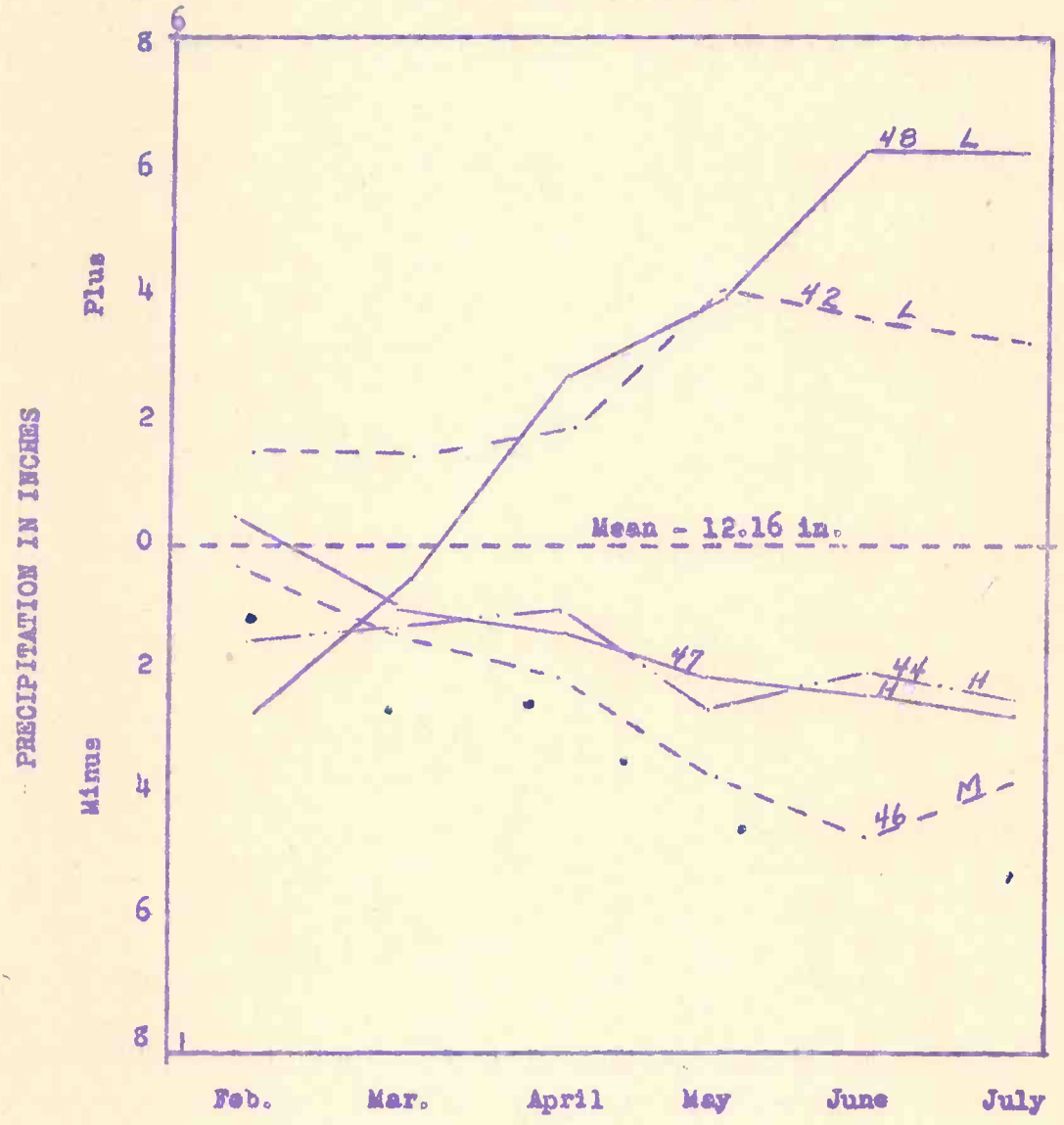


FIG. 15

ACCUMULATED VARIATION FROM MONTHLY MEAN PRECIPITATION

HAT CREEK

February through July



Legend

L - Light Ips Injury
M - Medium Ips Injury
H - Heavy Ips Injury

Distribution:

Craighead
Furniss
Evenden
Wygant
Hall
File copy
3 Extra copies